# Advanced Fiber-Optic / Optoelectronic /Photonic Module Manufacturing for Future Generation Military/Aerospace Applications

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# In2m Workshop Presentation Outline

- Avionics/Aerospace Fiber-Optic Network Components
- Workshop Question #1: Questions and Answers
- Recent Developments Support the In2m Concept
- Future Requirements Embrace the In2m Concept
- Summary

# First Generation Military/Aerospace Fiber-Optic Application Platforms

# Fiber-Optic Component Development Experiences

- Boeing 777 ARINC 636 Transmitter and Receiver
- Boeing 1773 Transceiver (Space Shuttle, Satellites)
- Air Force F-22 High Speed Data Bus and Fiber-Optic Transmitter/Receiver
- NASA International Space Station Fiber-Optic Transmitter and Receiver

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- Advanced Device, Process, Manufacturing Research and Development (including DARPA and NIST programs)

# In2m Workshop Issues are In-Synch with Military/Aerospace System and Component Design Issues

## In2m Size System Issues

- Affordability
- Durability
- Reliability
- Repeatability
- Stability

## High Level System Issues

- Affordability
- Lethality
- Supportability
- Survivability

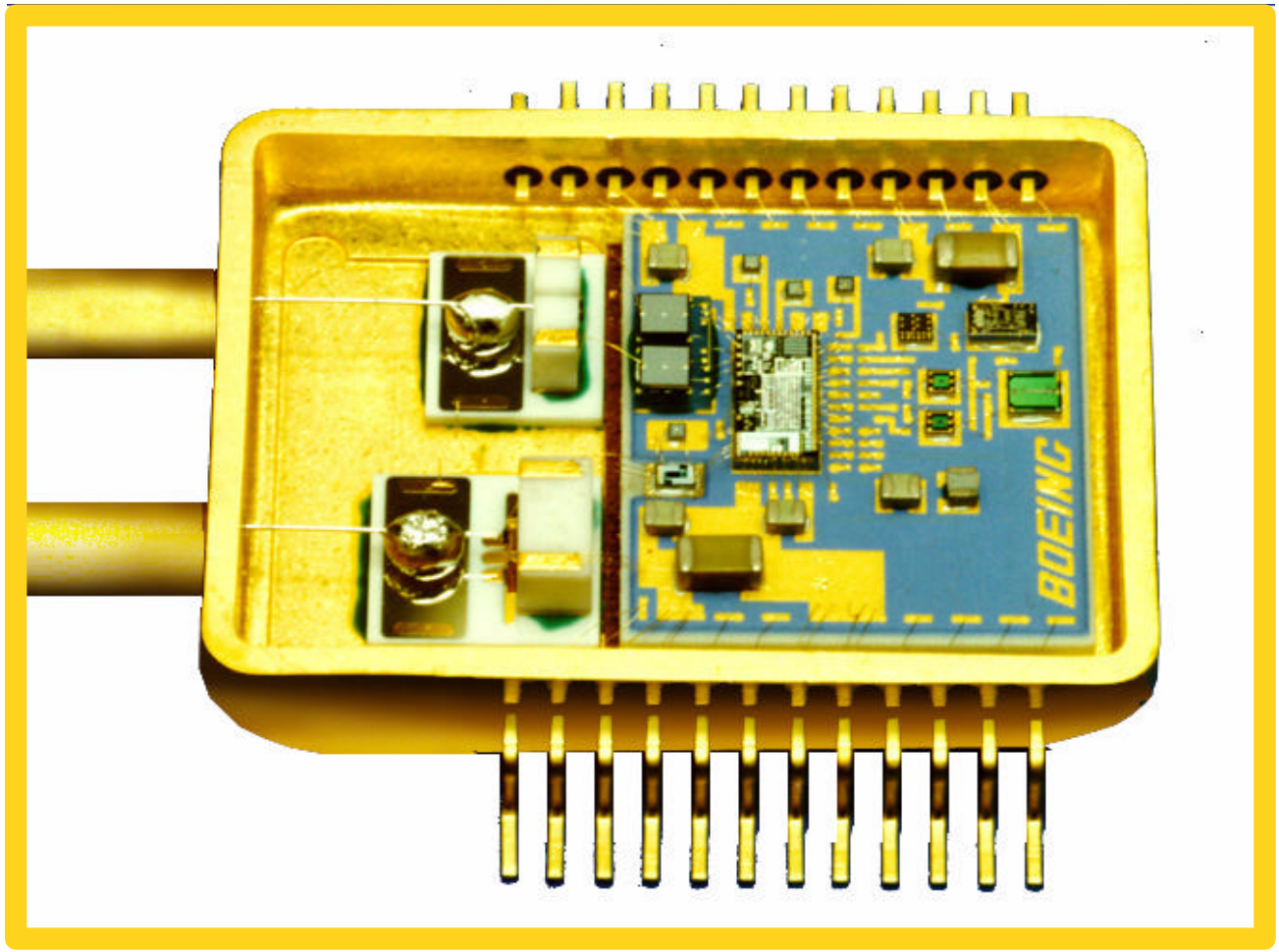
## Component Level Issues

- Manufacturability
- Producibility
- Reliability/Durability
- Testability

# Key Military/Aerospace Fiber-Optic Design, Process, and Manufacturing Engineering Challenges/Requirements

- **Hermeticity Lifetime/Alignment Lifetime**
  - 1,000+ temperature cycle qualification
  - Wider temperature extremes (I.e., -55 to +125°C)
  - 20-25 year lifetimes.
- **Small Form Factor (3.5 mm/0.140 in thick)**
- **Pressure Cycling (I.e., below sea level to 80,000 feet, below sea level to outer space, etc.)**
- **Vibration, Mechanical Shock, Thermal Shock, Acceleration, Moisture/Humidity, Salt Fog, etc.**
- **High Manufacturing Yield Required (100% Inspection and 100% Testing)**
  - Assembly processes must be very robust/repeatable
  - Assembly equipment must be very stable/repeatable
  - Inspection and testing must be labor efficient.

# Boeing AS1773 Transceiver



# First Generation Military/Aerospace Fiber-Optic Module Packaging Summary

- LED based links, multimode optical fiber, variable data rates, variable wavelengths, variable packaging solutions (MCM-C, LTCC, pigtailed, connectorized).
- Excellent performance and reliability.
- Little commonality other than
  - hermetically sealed
  - active alignment optical subassemblies.

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- Primary issues remain:
  AFFORDABILITY
  and
  TECHNOLOGY UPGRADE READINESS

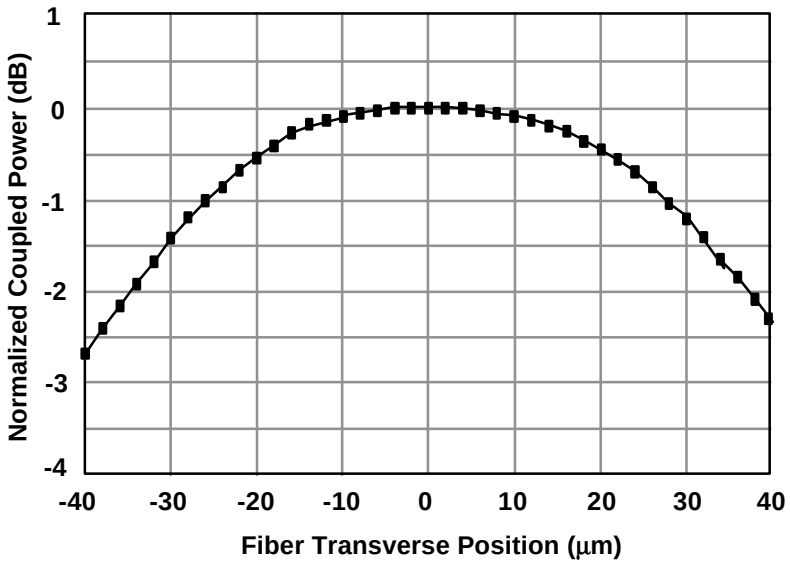
# In2m Workshop Questions and Answers

1) Are current equipment and practices able to meet the expected demands for part presentation, staging, placement, and fastening? No, No, No, No (current equipment and practices barely suffice for first generation fiber-optic component manufacturing).

2) Are these systems adaptable, and if so, will they be affordable? Somewhat Adaptable, Probably Not Affordable.

3) Are revolutionary solutions needed meet the demands expected by In2m? Yes, Future requirements will demand significant design, assembly, packaging, and manufacturing innovations.

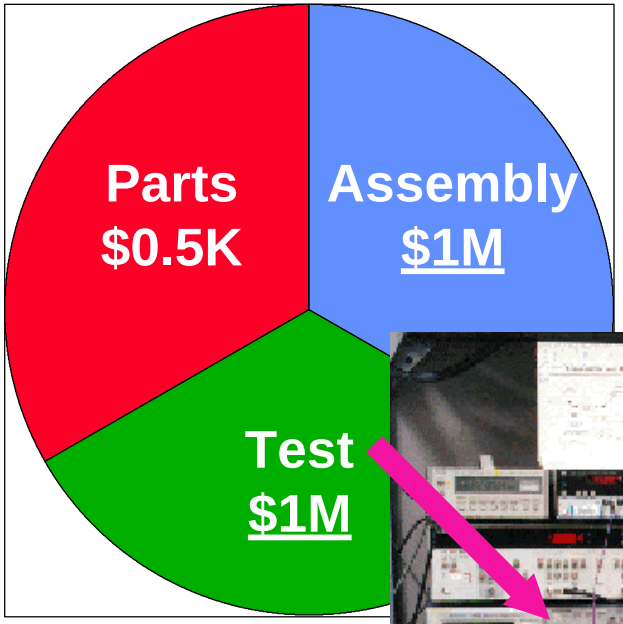
# Multimode Optical Fiber to LED Alignment

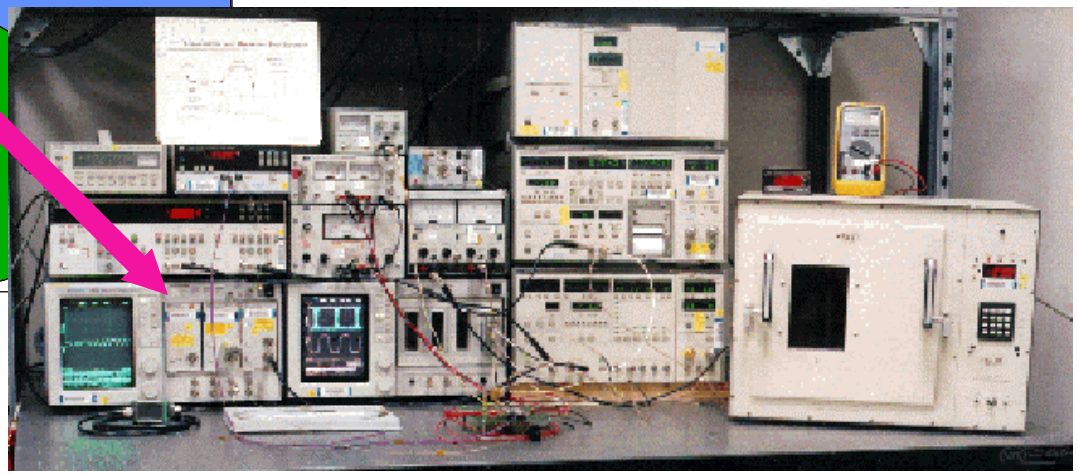



**+/- 10 μm**

**Note: Future Singlemode Fiber Based Systems Will Require +/- 1 μm to +/- 2 μm Assembly Precision.**

# In the Future: Current Assembly Equipment and Manufacturing Practices May Not Be Affordable

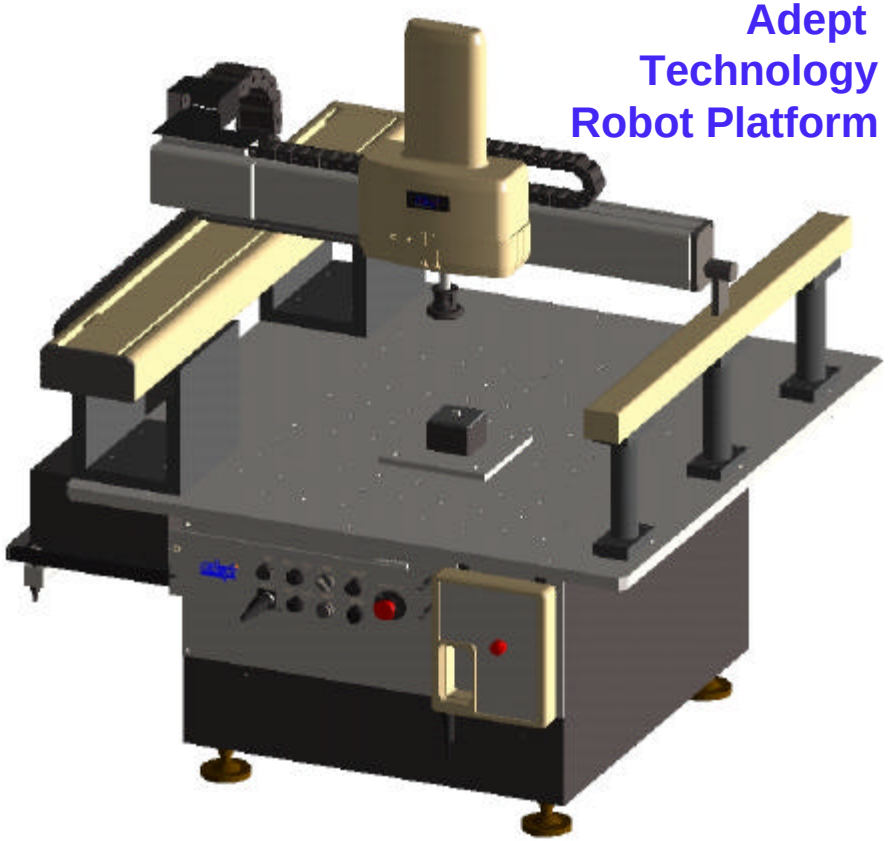


# Robotic Fiber-Optic Module Pigtailing

## NIST ATP Precision Optoelectronics Assembly Consortium

Adept Technology Robot Platform



**Goal**

Low-Cost Flexible Precision Assembly Platform and Processes.

**Key Milestones**

- Alignment / Bond Shift Characterization
- Automated OE Parts Feeding
- Machine Vision for Fibers and OE Devices
- Sub-micron Automated Alignment
- Automated Device Bonding

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# Active Alignment versus Passive Alignment

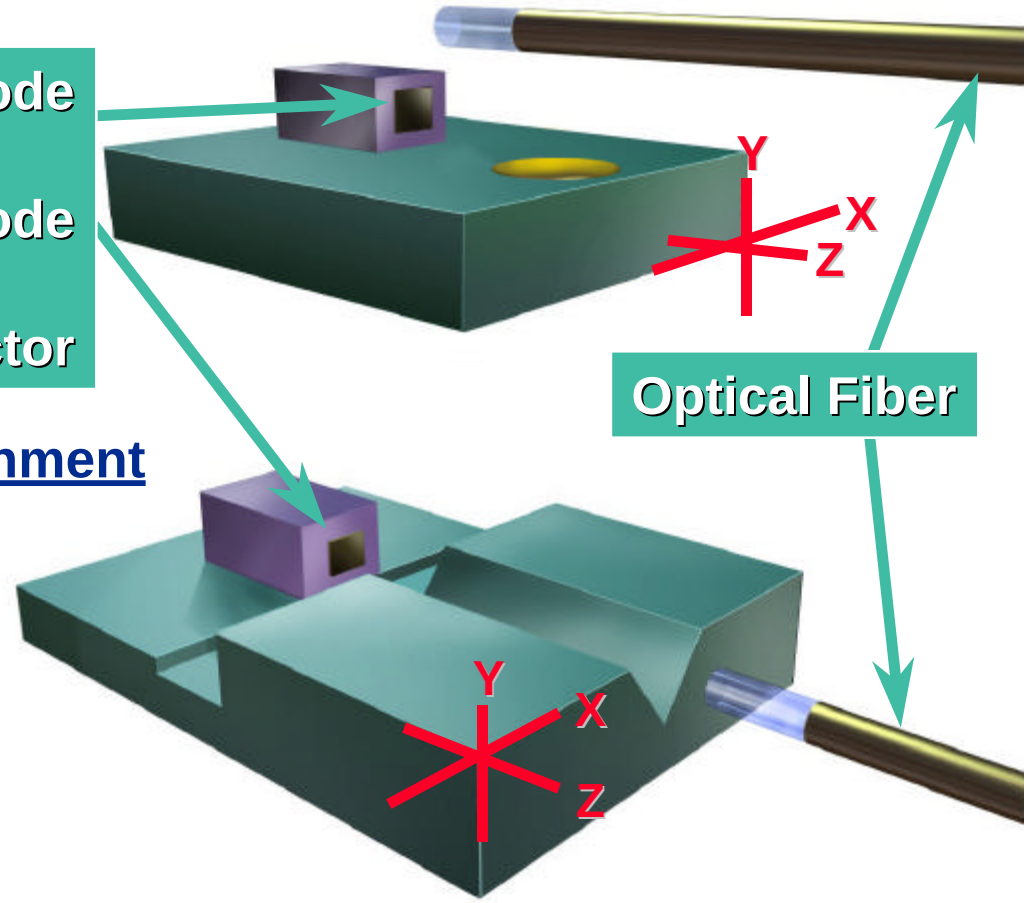
**Active Alignment**

Light Emitting Diode

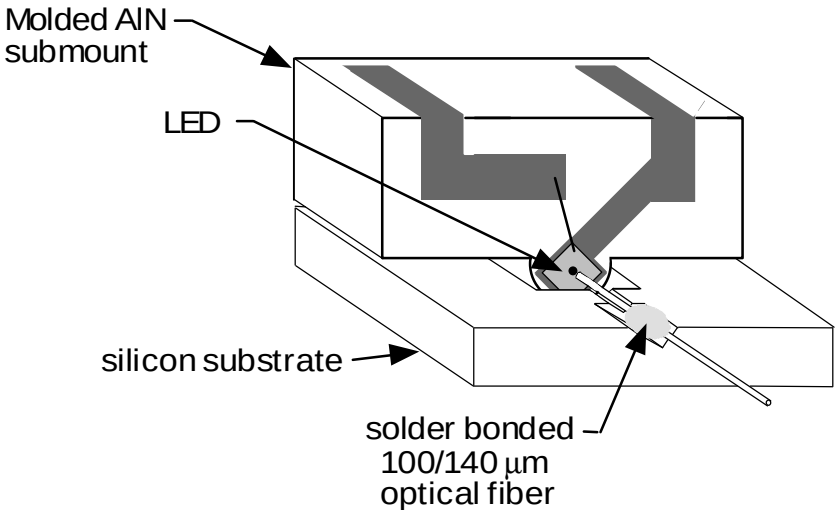
Laser Diode

Photodetector

**Passive Alignment**



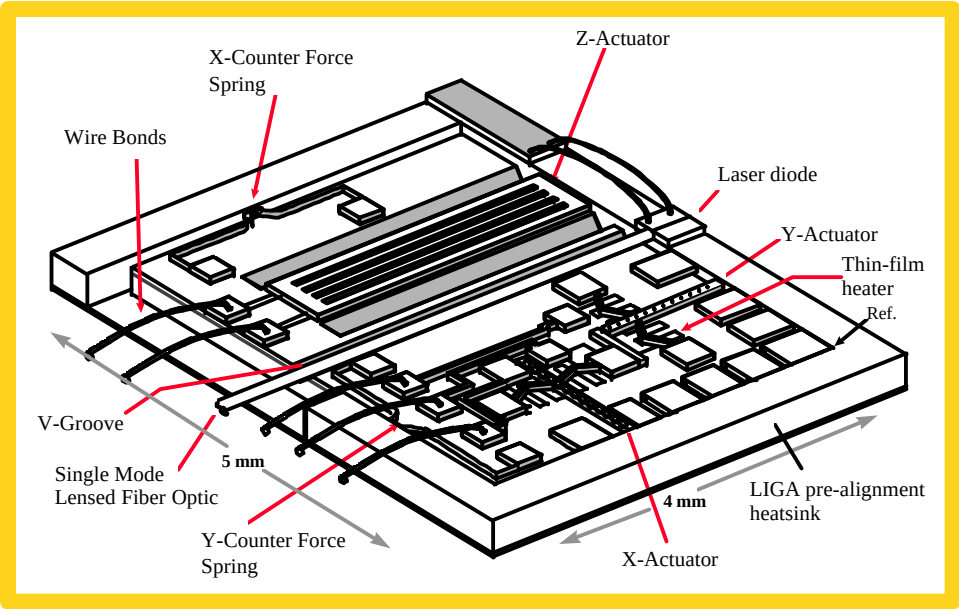
# Rugged, Durable Multimode Passive Alignment LED Optical Fiber Subassembly




- Wafer scale silicon micromachining
- Precision ceramic molded optoelectronic device submount
- 3D ---> 2D alignment

(Patent Pending)

# MEMS 3-Axis In Package Micro Aligner

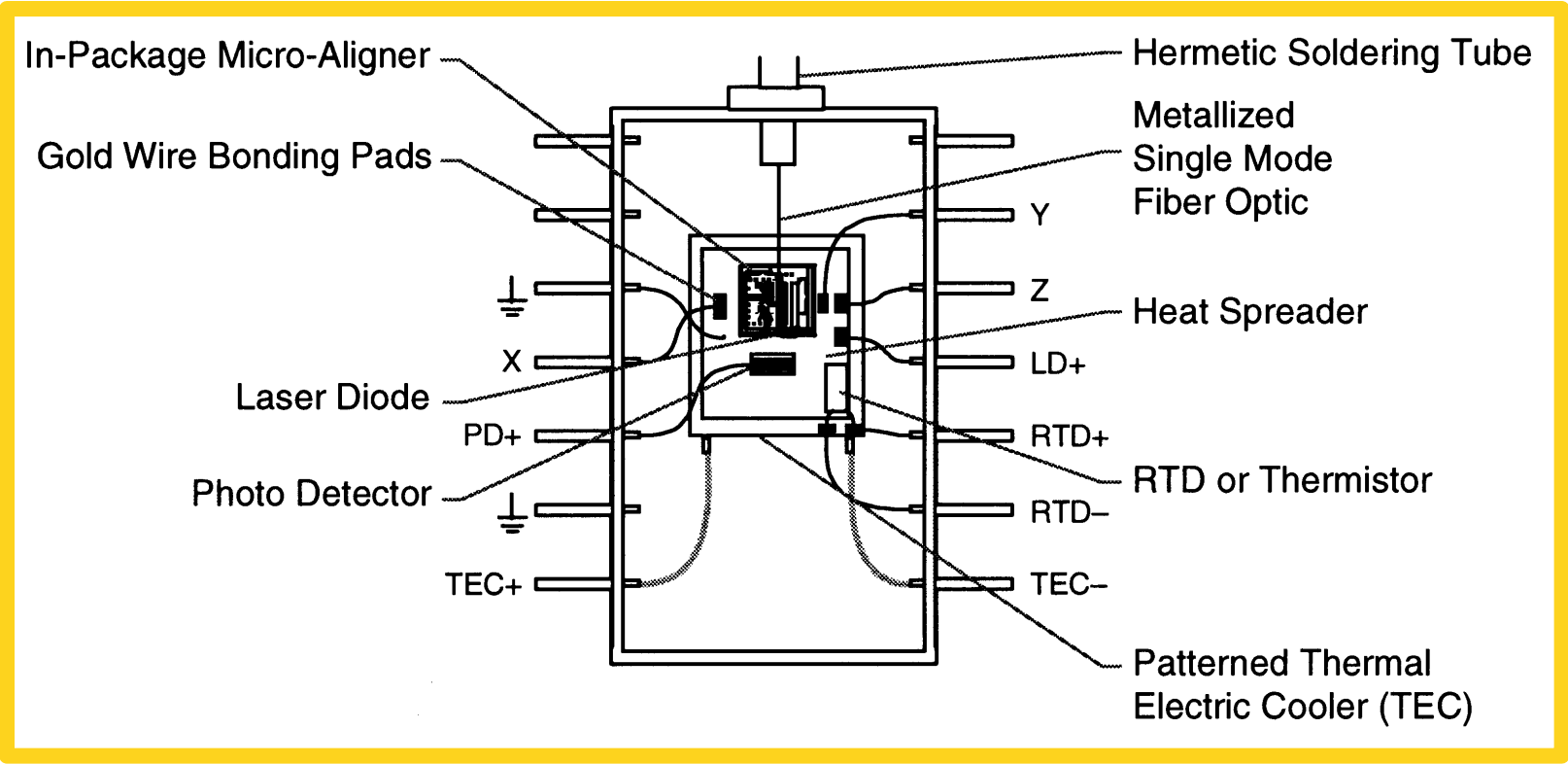



- MEMS device for 3 axis control of the attached optical fiber.
- Eliminates the need for external effectors for fiber-optic manipulating and fiber-optic pigtailing systems.
- Made by wafer scale silicon microbench and LIGA processing.
- Actuator forces and displacement sufficient for practical device pigtailing.
- Easily fits inside typical optoelectronic module housings.


***Reference:***

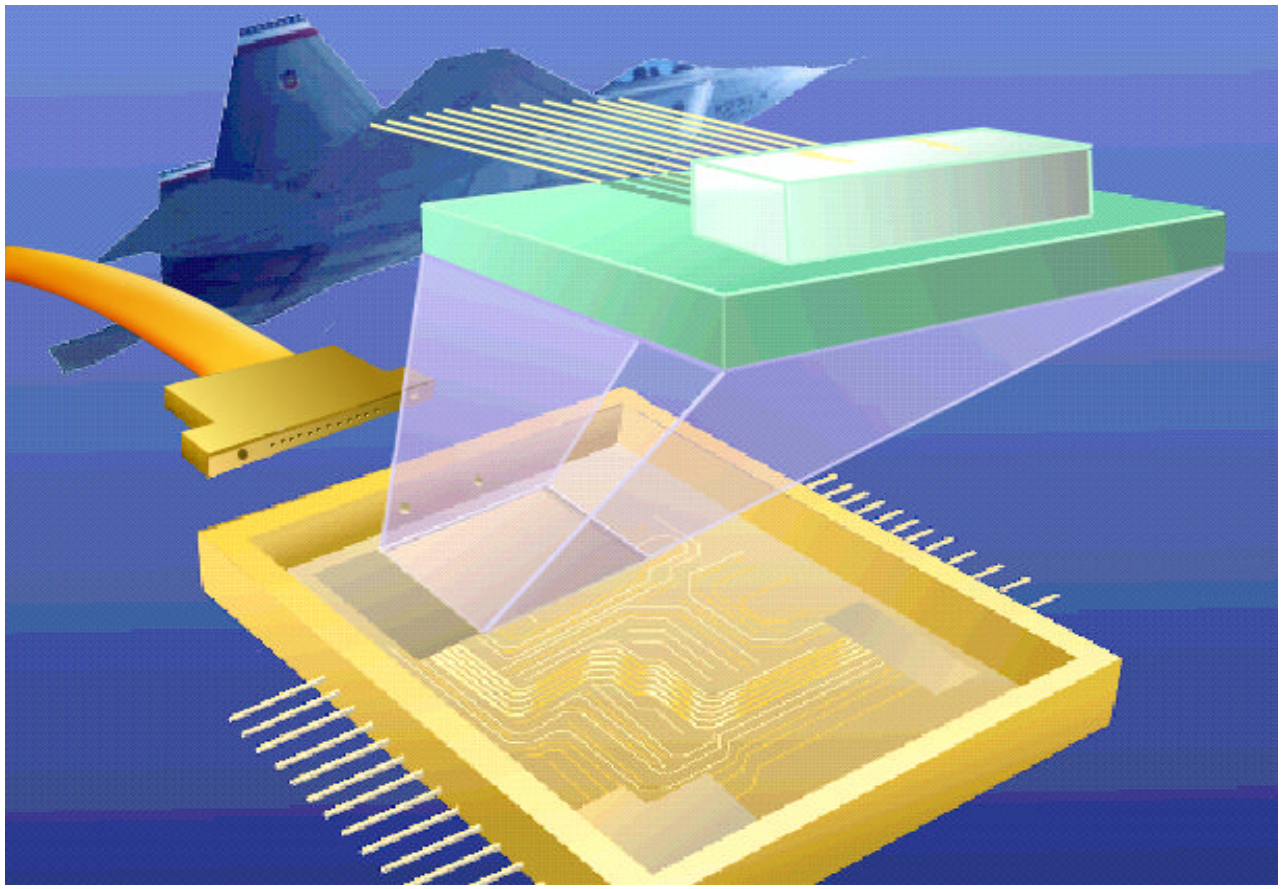
***48th IEEE Electronic Components and Technology Conf., Conference Proceedings, pp. 1446 - 1449, May, 1998.***

# MEMS In Package Micro Aligner
# Hybrid Fiber-Optic Laser Transmitter
# Package Layout

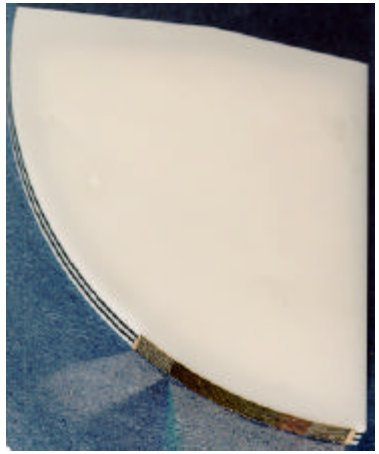


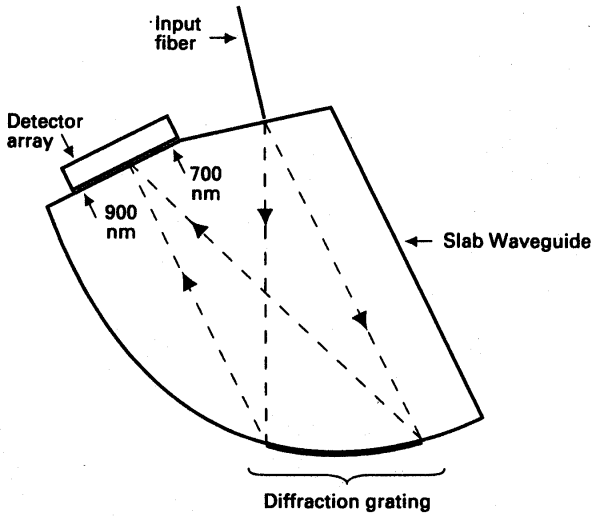

*Reference:*
*48th IEEE Electronic Components and Technology Conf., Conference Proceedings, pp. 1446 - 1449, May, 1998.*

# Ruggedized, Connectorized Array Transmitter and Receiver Module



# 16 Wavelength Optical Waveguide Spectrograph Wavelength Division Multiplexing Receiver






- Monolithic, manufacturable, durable, stable, packagable In2m precision device.
- Three different ceramic materials, CTE matched to within $1X10^{-6}$
- Replicated diffraction grating (~300 nm pitch)
- 10 nm (FWHM) resolution
- Interlayer spectral referencing


*References:*

*1) IEEE Components, Hybrids, and Manufacturing Tech., vol. 16, 1993.*

*2) IEEE J. Lightwave Tech., vol. 11, 1993.*

# Summary

- Packaging innovation played a key role in the success of first generation military/aerospace fiber-optic network development/deployment.
- More packaging innovation is required for:
  - First generation component cost reduction;
  - Next generation component development;
  - Affordable next generation component manufacturing.
- Forecasted next generation military/aerospace fiber-optic component requirements indicate new, higher precision, higher density, and more compact advanced fiber-optic components will be required. Assembly processes and assembly equipment developments must somehow keep pace……..

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